How the Coupled Spin, Orbital and Lattice Degrees of Freedom Can Cause Happiness or Distress in Asymmetric Magnetic Exchange Interaction, and Why It Matters for Microelectronic Applications

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Magnetic polar materials display an astonishing range of exotic properties, from multiferroics to topologically distinct spin textures (skyrmions) and related non-trivial topology. Skyrmions featuring a nanometric-sized particle nature are anticipated to play an essential role in a diverse array of demonstrations, from new knowledge in electronic and magnetic states of matter to multi-state high-density magnetic memory architectures. However, the coupled spin and orbital degrees of freedom in concert with the appropriate crystal lattice that facilitate skyrmions formation are not well understood. Using the example of 3d transition metal iodates, we demonstrate how the coupling between the spin-orbital effects and the lattice symmetry profoundly impacts the asymmetric exchange interaction of these polar magnets, thus their magnetic spin states. The chemical approach of studying carefully these complexes enables us to systematically tune spin states, orbital contribution, and lattice symmetry. The magnetic spin evolution and the thermodynamics of the ground state of these polar magnets were achieved by combining dc and ac magnetization and specific heat measurements. Their magnetic ground state and estimated asymmetric exchange interaction underpinning the relative happiness or distress of putative skyrmions emergence were obtained from neutron diffraction experiments. We share the results and knowledge gained from this work, and the demonstration of the potential requirements for stabilizing skyrmion lattice.